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Canada Centre for Mineral and Energy Technology

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Summary Report No. 7: Gypsum and Anhydrite

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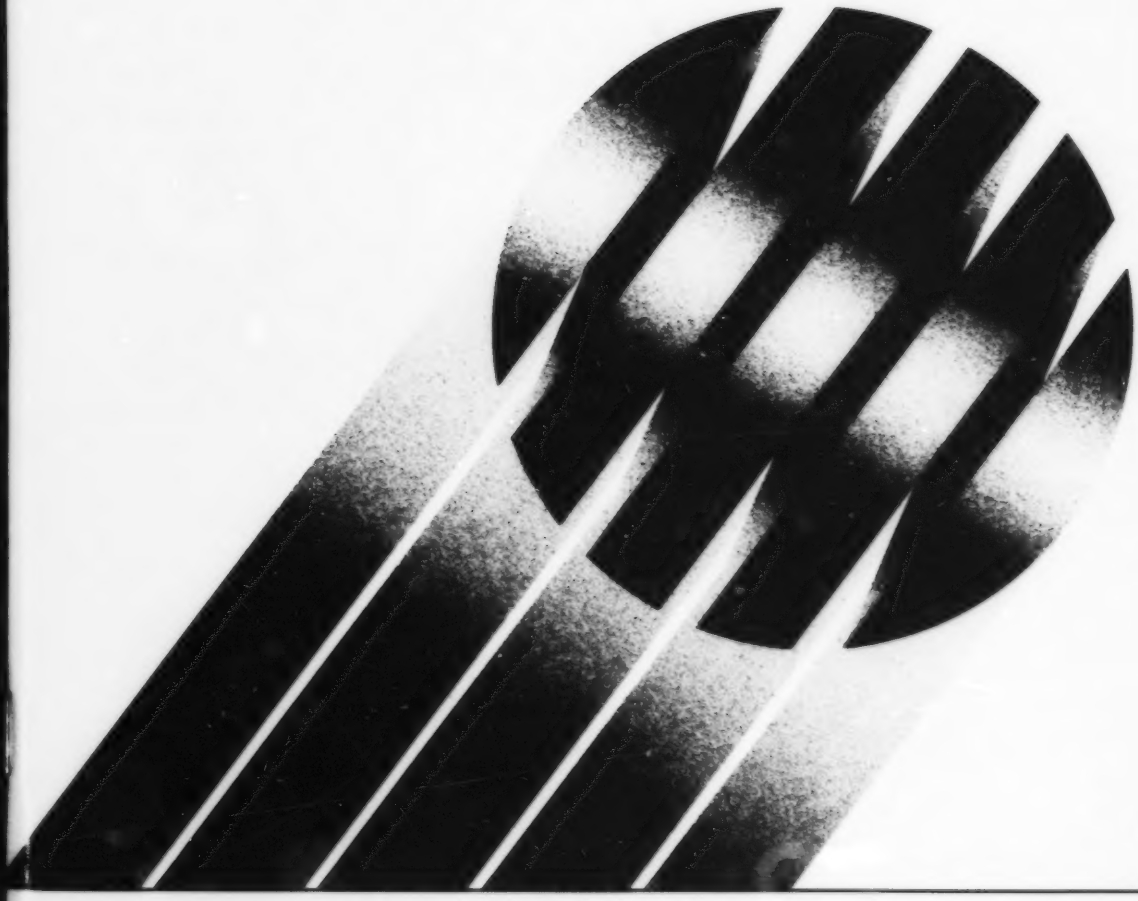

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SUMMARY REPORT NO. 7: GYPSUM AND ANHYDRITE

R.K. COLLINGS and P.R.A. ANDREWS
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SUMMARY REPORT NO. 7: GYPSUM AND ANHYDRITE

by

R.K. Collings* and P.R.A. Andrews**

Abstract

Gypsum and anhydrite occur in most provinces of Canada. The deposits that are of economic significance are in Newfoundland, Nova Scotia, Ontario, Manitoba and British Columbia. The principal gypsum producers, Domtar Inc., Westroc Industries Ltd., U.S. Gypsum Corp. and Atlantic Gypsum Ltd., collectively have gypsum plaster and wallboard plants in most provinces.

Calcined gypsum is principally used in the manufacture of gypsum wallboard and gypsum plaster products. Crude gypsum and anhydrite are widely used as set-control agents in Portland cement production.

Lesser uses are as agricultural fertilizer, where a supply of calcium and sulphur is needed for certain crops, and as a neutralizer for alkaline soils. Ground white gypsum and anhydrite may be used as fillers in paint and paper, as additives to oil well-drilling fluids to increase calcium ion concentration, and as refining agents in bottle-glass manufacture.

Gypsum, chemical gypsum, and anhydrite samples were studied extensively by CANMET and its predecessor, Mines Branch, between 1915 and 1985. Summaries of the more important studies are presented in the Appendix.

Keywords: Gypsum, chemical gypsum, anhydrite, production, uses, beneficiation, CANMET reports.

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RAPPORT SOMMAIRE NO 7: GYPSE ET ANHYDRITE

par

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Résumé

Il existe du gypse et de l'anhydrite dans la plupart des provinces du Canada. Les gisements économiquement exploitables se trouvent à Terre-Neuve, en Nouvelle-Ecosse, en Ontario, au Manitoba et en Colombie-Britannique. Les principaux producteurs de gypse, la Domtar Inc., la Westroc Industries Ltd., la U.S. Gypsum Corp. et l'Atlantic Gypsum Ltd., disposent collectivement d'usines de panneaux de placoplâtre dans la plupart des provinces.

On emploie principalement du gypse cuit pour fabriquer des panneaux de reêtement en placoplâtre et des produits à base de plâtre. On emploie à grande échelle du gypse et de l'anhydrite bruts comme agents du contrôle du durcissement, lors de la production de ciment Portland.

Parmi les usages secondaires, on emploie le gypse et l'anhydrite comme engrais, là où certaines récoltes nécessitent un apport de calcium et de soufre, et comme neutralisant des sols alcalins. On peut aussi employer le gypse et l'anhydrite blancs finement broyés, comme matières de charge dans les peintures et les papiers, et comme additifs des fluides de forage de puits, pour augmenter la concentration des ions calcium, et comme agents d'affinage lors de la fabrication du verre à bouteilles.

CANMET et son prédécesseur, la Direction des mines, ont étudié entre 1915 et 1985 des échantillons de gypse, de gypse artificiel, et d'anhydrite. Dans l'appendice, sont présentés des résumés des études les plus importantes.

Mots clés: Gypse, gypse artificiel, anhydrite, production, usages, enrichissement, rapports de CANMET.

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INTRODUCTION

A CANMET survey of Canadian industrial mineral producers (1) identified a number of problems specific to the industry, as well as potential opportunities for further development and expansion. The response to this survey, and subsequent discussions with industry and government specialists, identified a requirement for information in a number of areas. These areas included mineral deposits, processing, beneficiation studies and new developments, as well as information on product specifications and potential markets for Canadian industrial minerals.

The response to this requirement was a decision to compile related information on file at CANMET and, as available, from provincial government offices and the private sector in a series of Summary Reports on a number of industrial minerals. The information for each mineral pertains to mineral occurrences, deposits of specific interest, current activities, product uses and specifications, process technology, and summaries of past R&D on specific deposits by CANMET and others. This report, *Summary Report No. 7: Gypsum and Anhydrite*, is the seventh in the series. The first six were on Barite, Celestite, Fluorite, Silica, Mica and Vermiculite, and Graphite.

GYPSUM

Mineralogy

Gypsum, hydrated calcium sulphate, $CaSO_4.2H_2O$, crystallizes in the monoclinic system. The common crystal forms are combinations of prism, clinopinacoid and negative hemipyramid; twinning is common as the swallow-tail and the arrow-head type. The cleavage is perfect, parallel to the clinopinacoid giving very thin, flexible, non-elastic plates. Gypsum most commonly occurs in laminated, granular or compact masses and in fibrous forms.

Gypsum crystals are usually colourless. Massive varieties are colourless or white, occasionally grey, yellow or red. The lustre varies from shiny and pearly on cleavage planes to sub-vitreous on other surfaces. The massive varieties may glisten but more usually are dull and earthy, while the fibrous forms are silky in texture.

Gypsum crystals are transparent to translucent; massive gypsum is generally opaque. The mineral is very soft with a hardness of 1.5 to 2.0. The specific gravity at 2.3, is less than that of quartz. Gypsum also occurs as a number of varieties, including selenite, alabaster, satin spar and gypsite. Gypsum is slightly soluble in water, soluble in dilute hydrochloric acid, and insoluble in sulphuric acid.

Principal Occurrences

The gypsum deposits of Canada have been described by numerous investigators (2–33). Deposits of commercial size and purity occur in Newfoundland, Nova Scotia, New Brunswick, Quebec, Ontario, Manitoba, Alberta and British Columbia. These are briefly summarized by province below.

Newfoundland (11–13)

Large gypsum deposits occur in the southwestern section of the province in the Bay St. George area, the chief occurrence being at Flat Bay. Deposits also occur in the Boswarlos–Piccadilly area, near the mouth of Romaines River, along the banks of Sheep Brook and Coal Brook, and in the valley of Crabbs River. Numerous zones of gypsum are exposed along the beaches near Ship Cove and at Plaster Cove. Some deposits measure up to 100 m in thickness and overburden, where present, may measure up to 3 m. Associated interbedded rocks include shale, limestone, sandstone, conglomerate and anhydrite. Early exploration of these deposits was undertaken in 1926, but development on a commercial basis was only initiated in 1952, when Atlantic Gypsum Limited began manufacturing gypsum wallboard at Humbermouth, near Corner Brook, using gypsum quarried at Flat Bay. Production at Flat Bay has continued to the present, the quarried gypsum being used in gypsum products manufactured at Humbermouth, in cement manufacture at Corner Brook, and for export. Reserves in the area are estimated to be 40 Mt.

Nova Scotia (14–18)

Some of the largest known deposits of gypsum in Canada occur in Nova Scotia, with occurrences largely being confined to the northern half of the mainland and to Cape Breton Island. These deposits are in Hants, Cumberland and Antigonish counties and, on Cape Breton Island, in Victoria, Richmond and Inverness counties. Most deposits are near the surface and overburden seldom exceeds 10 m in thickness. The deposits usually are associated or interbedded with limestone, shale and clay, and underlain by anhydrite. Gypsum was quarried as early as 1770 by Nova Scotian farmers who sold it to the United States for use as a fertilizer. Several companies were formed during the early part of the 19th century to quarry gypsum for export to gypsum-product plants in the United States. Exports to the United States today account for over 90% of the gypsum mined. The principal quarries are located at East Milford, Halifax county; Windsor, Hants county; Little Narrows, Victoria county; and River Denys and Sugar Camp, Inverness county. A quarry at McKay Settlement, near Windsor, supplies gypsum for plaster manufacturing at Windsor. Gypsum for cement manufacture at Brookfield, Colchester county, is obtained from a nearby quarry.

New Brunswick (19–20)

The chief gypsum deposits in New Brunswick are in the southeast, in the vicinity of Hillsborough, Albert county. Deposits may measure up to 20 m or more in thickness, and generally are underlain

by beds of limestone and/or anhydrite. Overburden, consisting of soil and clay, may be up to 3 m or more in thickness. Gypsum also occurs in Kings and Westmorland counties in southern New Brunswick. Some of these deposits were operated as early as 1816 by farmers who used the gypsum for crop-fertilizing. The Hillsborough deposits were operated for many years beginning in 1854 with the construction of a crushing and calcining plant. A wallboard plant erected in 1912 continued to produce wallboard for consumption in the Maritimes until its closure in 1982. Gypsum is today mined at Intervale, near Havelock, for use in Portland cement manufacture at Havelock. Minor production of gypsum has been recorded from deposits at Cape Maringouin, Albert county, and at Fox Hill and Upham, Kings county.

Quebec (21, 22)

The only known significant occurrences of gypsum in Quebec are on the Magdalen Islands in the Gulf of St. Lawrence. The largest deposits are found on Grindstone, Alright, Amherst and Entry Islands. The gypsum outcrops over wide areas and is relatively thick, measuring up to 15 m or more in many places. There is no commercial development of this gypsum at present.

Ontario (23-25)

Gypsum occurs at a number of locations in Ontario, but interest largely is confined to those deposits of the Grand River area of southern Ontario and, in the northeast, to deposits in the Moose River area south of James Bay. Gypsum in the Grand River area occurs as relatively narrow 1 to 3 m seams at depths up to 115 m and usually is associated or interbedded with limestone and/or dolomite. In the Moose River area, good exposures of gypsum occur along the riverbank near Moose River village and along the banks of the Cheepash River about 30 km above its juncture with Moose River. Large deposits also occur at Gypsum mountain, 20 km southeast of Moose River village. Many of the gypsum beds are exposed over a 5 m thickness and overburden, consisting of clay with intermixed sand, limestone and shale, may measure up to 10 m or more in thickness in some areas.

The beginning of the gypsum mining industry in Ontario dates back to the early 19th century when gypsum was mined near the town of Paris and applied to clover crops. The first underground mine was opened in 1822, and a calcining plant was erected near Paris in 1896. Various mines and plants were operated since that time, but there are only three mines in current production. These are at Hagersville, Caledonia and Drumbo. Gypsum from Hagersville and Caledonia is utilized on-site for gypsum plaster and wallboard manufacture. Gypsum from Drumbo is used for plaster and wallboard manufacture at Mississauga.

Manitoba (26-29)

Gypsum occurs at a number of locations in the southern part of Manitoba: at Gypsumville, 250 km north of Winnipeg; at Amaranth, 150 km northwest of Winnipeg; and at depth at Silver Plains near

Dominion City, 100 km south of Winnipeg. The Gypsumville deposits measure 10 m or more in thickness and are usually underlain by anhydrite. Overburden consists mostly of glacial till and seldom exceeds 2 m in thickness. These deposits have been quarried since the early 1900's to provide gypsum for gypsum products manufacture, initially at a plant on Portage Bay, Lake Manitoba, and later, at Winnipeg.

Gypsum at Amaranth occurs near the surface as well as at depth. Underground mining operations to recover gypsum from interlayered gypsum/anhydrite beds at a depth of 35 m were carried out during several periods beginning in 1929. Today gypsum is obtained from near surface deposits at Amaranth for the production of wallboard at Winnipeg.

The Silver Plains gypsum is sub-surface. Mining was carried out at a depth of 100 m during the period 1964 to 1975. Operations were discontinued in 1975, due to water conditions in the mine and low ore grades.

Alberta (30)

A number of gypsum deposits are known in Alberta, but none has been developed commercially because of difficult accessibility, remoteness, or location in National Parks. Hamilton (30) describes several deposits: at Kananaskis near Kananaskis Lakes, 100 km northwest of Calgary; at Head Creek, 80 km southwest of Calgary; and at Mowick and Featherstonehaugh Creeks near the Alberta/British Columbia border, west of Entrance. Deposits are also documented in a wide area around Fort McMurray: near Peace Point on the Peace River, 270 km north of Fort McMurray; at Clearwater River about 50 km east of Fort McMurray; and on the Athabasca River, 100 km north of Fort McMurray. Other deposits occur at Salt River, in the northwest corner of the province, west of Slave River, and near the Alberta/Northwest Territories border. Hamilton reports that the Peace Point and Fort McMurray deposits have the best potential for development. The Peace Point deposits are 5 to 10 m thick, contain good quality gypsum, and reserves are estimated at 1 billion t. The Fort McMurray gypsum deposit on the Athabasca River is less remote, but is of lower grade and would require higher cost underground mining.

British Columbia (31-33)

The gypsum deposits of British Columbia are well described by Butrenchuk (33). The main occurrences of commercial gypsum are in the Stanford Range of the Rocky Mountains in the southeastern section of the province within 100 km of the Alberta border. These include deposits at Windermere Creek, 10 km east of Windermere; in the Kootenay-Nine Mile Creek area, 10 to 15 km east of Canal Flats; and in the Lussier River-Coyote Creek area, 20 km east of Skookumchuk. Gypsum is quarried in both the Windermere and Lussier River areas for gypsum products manufacture at plants in Vancouver, Calgary and Edmonton. These deposits vary from 50 to 100 m in thickness, are interbedded with limestone and dolomite, and usually are underlain by anhydrite. Gypsum reserves of the Stanford Range deposits are estimated to be 160 Mt (33). The most favourable areas

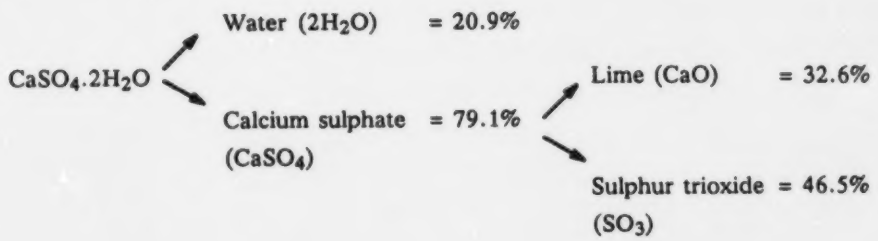
for future exploitation are on the west side of the Kootenay River along the Lussier River, south of the Lussier quarry, and in the area near Coyote Creek. Other gypsum deposits are noted including those in the Mayook – Bull River – Chipka Creek area, east of Cranbrook; at Joffre Creek near the Alberta border, 65 km east of Invermere; and to the north, near the Alberta border, at Forgetmenot Creek, 60 km north of McBride. Gypsum occurs farther west, at Falkland, 60 km east of Kamloops, and in the far northwestern corner of the province on the O'Connor River (32). The Falkland gypsum, first mined in 1926, is currently used in the manufacture of cement at Kamloops. There is also interest in developing the O'Connor River deposit to supply markets in the Pacific northwest (8).

Northwest Territories

Gypsum has been noted at a number of locations in the Northwest Territories. It occurs, as narrow seams, along the north shore of Great Slave Lake in the vicinity of Gypsum Point, and along the banks of the MacKenzie and Great Bear rivers near Fort Norman. Other occurrences are found along the banks of Slave River north of Fort Smith, and on several of the Arctic Islands.

Technology and Uses

Gypsum may be broken down into the following constituent components:



When gypsum is heated (calcined) at a comparatively low temperature (110° to 165°C), it loses 75% of its water of crystallization. The calcined gypsum, commonly known as plaster of Paris, recombines readily with water and sets to form a hard dense plaster. Gypsum is calcined in a batch or continuous-type kettle and occasionally in a rotary kiln. The continuous-type calcining kettle method is a relatively new development. Other types of calciners include the air-swept impact hammer mill where the gypsum is crushed and calcined by hot gases, and the Calcidyne system where ground gypsum is calcined by hot gases in a cyclone-type calciner. The crude gypsum is usually reduced to 150 mm for kettle calcining. The rotary kiln takes a coarser, 50 mm feed. The product is reduced to 150 mm following calcining.

Plaster of Paris usually sets in 10 to 20 min when mixed with water, however, the setting process may be accelerated or retarded by the addition of various chemicals. Raw gypsum and set plaster are strong accelerators. Other common accelerators are potassium sulphate and alum. Retarders are

protein derivatives and chemical chelating agents. The most common retarder used by the industry is diethylene triamine pentacetic acid (DTPA). Glues and sugars also have a strong retarding effect in gypsum plaster.

Vast amounts of calcined gypsum are used by the building construction industry. Calcined gypsum is the main constituent of gypsum board, lath and tile, and of most industrial plasters. Gypsum lath is used in buildings as a base for plaster, whereas gypsum board is used without plaster for sheeting interior walls and ceilings. Exterior walls may be covered by gypsum sheathing, an asphalt impregnated gypsum product.

High-purity calcined gypsum is used in dentistry to make plaster casts for plate work, and by the medical profession for surgical casts to support fractures. Specialized plasters include pre-mixed gypsum plaster with barytes ($BaSO_4$) as aggregate for use as a radiation shielding material, and sound absorbing acoustic plasters which contain pumice as a pre-mixed aggregate. Finely ground calcined gypsum is used by the glass industry as a bedding plaster to support large sheets of plate glass during polishing operations. Calcined gypsum is also used as a moulding plaster by the foundry and ceramic industries for casting machine parts and ceramic pieces.

Crude uncalcined gypsum and anhydrite are used as set-control agents in Portland cement, where about 5% by weight of gypsum and/or anhydrite is interground with the calcined cement clinker. Crude gypsum, reduced to 400 μm or finer and known as mineral white or terra alba, is used as a filler in paint and paper. It may also be used as a substitute for salt cake in glass manufacture. Ground gypsum is used as a soil conditioner to offset the effect of black alkali, to restore impervious or dispersed soils, and as a fertilizer for peanuts and other leguminous crops.

Gypsum and anhydrite are potential sources of sulphur compounds. In Europe, gypsum or anhydrite is calcined at high temperatures with coke, silica and clay to produce sulphur dioxide, sulphur trioxide and by-product cement. The two gases are then converted into sulphuric acid. Gypsum and anhydrite from Cape Breton, Nova Scotia, are currently being considered as sources of sulphur.

Hydrated calcium sulphate is produced at several locations in Canada as a by-product of phosphoric and hydrofluoric acid manufacture, and may be produced by desulphurization facilities at coal-burning power plants. These "chemical" gypsums are presently considered to be waste products.

Specifications

There are no precise specifications for either gypsum or anhydrite, but the industry recognizes several impurities or contaminants which are detrimental for certain uses. These include clay, shale, anhydrite, dolomite and limestone, as well as small amounts of iron oxides, silica and sodium chloride. The highest quality rock has a good white colour, is free of contaminating clay, and may contain more than 99% $CaSO_4.2H_2O$. High-grade gypsum is used in the manufacture of barium plasters, plaster of Paris for specialized moulding purposes, surgical and medical plasters, as a filler

in paint, and in the brewing of beer. Lower-grade gypsum, containing more than 90% $CaSO_4.2H_2O$, is used as a moulding plaster in the pottery industry, in the manufacture of wall plasters and plasterboard, in Portland cement and as a soil conditioner. Plaster and plasterboard manufacture requires that soluble salts, i.e., sulphates and chlorides of sodium, potassium and magnesium, should not exceed 0.2% by weight as they give rise to efflorescence. The presence of anhydrite tends to lower the strength of wall plasters.

A minimum of 92% $CaSO_4$ is generally required for anhydrite used in sulphuric acid manufacture.

Mining, Processing and Utilization

Mining

Commercial gypsum usually occurs in massive, finely crystalline, bedded deposits, although vein and lens-like deposits are also known. Gypsum is mined from surface or near-surface deposits by quarrying. Deposits that occur at depth are developed by underground mining. Most surface deposits are covered by overburden which must be removed before the gypsum can be quarried. Overburden that exceeds 5 m in thickness is commonly removed by large drag-line scrapers. Lesser thicknesses of overburden are removed by combined shovel-truck or tractor-scraper operations and bulldozing. Gypsum quarries are developed by benching; the benches are usually 15 m or more in width and 5 to 10 m or more in height.

Underground gypsum deposits are mined by standard room and pillar methods with 6 to 7 m rooms and 5 to 6 m pillars. The width or depth of gypsum mined is dependent on the thickness and purity of the seam. For example, at Hagersville, in southern Ontario, a 1.2 m seam is mined; at Caledonia, near Hagersville, the seam is 2.7 m; and at Drumbo, northeast of Woodstock, the seam is 1.5 m thick.

Processing and Utilization

Crude gypsum from the quarry or mine, which may measure up to 1 m in size, is reduced to about 150 mm by jaw, gyratory or single slugger-roll crushers prior to being shipped to gypsum processing plants.

Impurities associated with Canadian gypsum deposits include mud, silt, dolomite, limestone and anhydrite. The percentage of dolomite, limestone or anhydrite is minimized by selective mining or quarrying, and large pieces may be removed by sorting at the quarry face. Mud and silt may be reduced by coarse crushing followed by washing and screening. Heavy-media spiral separators are used at Windsor, Nova Scotia and at Hagersville, Ontario to separate gypsum from anhydrite and dolomite. Dolomite and limestone are removed to a substantial degree at several Canadian plants by selective crushing and screening or air separation. The gypsum, being softer than the contaminating minerals, is reduced more readily and tends to concentrate in the finer fractions.

The next stage, following preliminary crushing and grinding, is calcining. Most companies prefer to calcine a coarser minus 200 to 300 μm product and to grind to 150 μm following calcining using roller, ball, tube and jet mills. Gypsum is calcined in kettles, or in rotary kilns similar to those used for cement manufacture. The more common kettle process may be a batch or continuous operation, the latter process is a relatively recent adaptation.

The gypsum kettle, which is peculiar to the gypsum industry, consists of a vertical cylinder, 2.5 to 4.5 m in diameter and from 2.5 to 4 m high, made of boiler plate set in a shell of brickwork. The kettle is fired from below by oil or gas. The hot gases circulate around the inner shell of the kettle and through horizontal, 20 to 35 cm diameter flues which pass through the kettle. A 10 to 20 t charge is loaded through ports in the top of the kettle. The gypsum is agitated constantly during calcining by horizontal rabble arms attached to a central, vertical, gear-driven shaft. Drag chains attached to the lower rabble arms keep the gypsum from sticking to the bottom. The retention time is about 45 min in continuous kettles. The calcined gypsum product (plaster of Paris or stucco) is discharged into storage bins or "hot pits" where it is allowed to cool for 30 min. It is then transferred by belt or drag chain conveyors and bucket elevators to the plaster plant for further processing.

A plant at Corner Brook, Newfoundland, calcines in a rotary kiln. The gypsum is reduced to minus 50 mm or finer and fed into the slowly revolving kiln. The temperature at the intake end usually averages 120°C and, at the discharge end, about 150°C; retention time is 35 to 40 min. The calcined gypsum is reduced to 150 μm by roller mill following discharge from the kiln and transferred to the plaster or board plant.

Calcined gypsum for wall plaster may be reground in tube mills to produce a flake-like grain that is preferred by the plaster trade. Various additives, e.g., retarder, organic and inorganic fibres, expanded perlite or vermiculite, are mixed with the plaster and the whole mixture is then packaged for shipment.

Plaster of Paris used in the manufacture of gypsum lath and board normally is not reground. Land plaster (ground gypsum used to accelerate the setting process), starch, foam and other ingredients are added and the whole mixed with water in standard pin or scraper mixers to form a slurry for gypsum wallboard or lath production. Slurry from the mixer is introduced between two layers of absorbent paper to form a sandwich which is then fed through a standard board-forming machine. This unit consists of two large forming rolls with auxiliary equipment for scoring, turning, and gluing the edges of the paper.

The board-forming unit is easily adapted to the manufacture of gypsum lath and the various thicknesses of gypsum board. The plaster board issuing from the forming rolls is supported and carried along by a conveyor system consisting of a continuous rubber belt followed by rollers. Belt speeds vary between 30 and 90 m/min. The plaster core sets as the board is carried forward by the conveyor system. It is then cut into 2.5, 3.0 or 3.5 m lengths by a rotary cutter. The cut boards are introduced into a tunnel drier by a mechanical roller-conveyor loading tipple. The drier is 100 m or

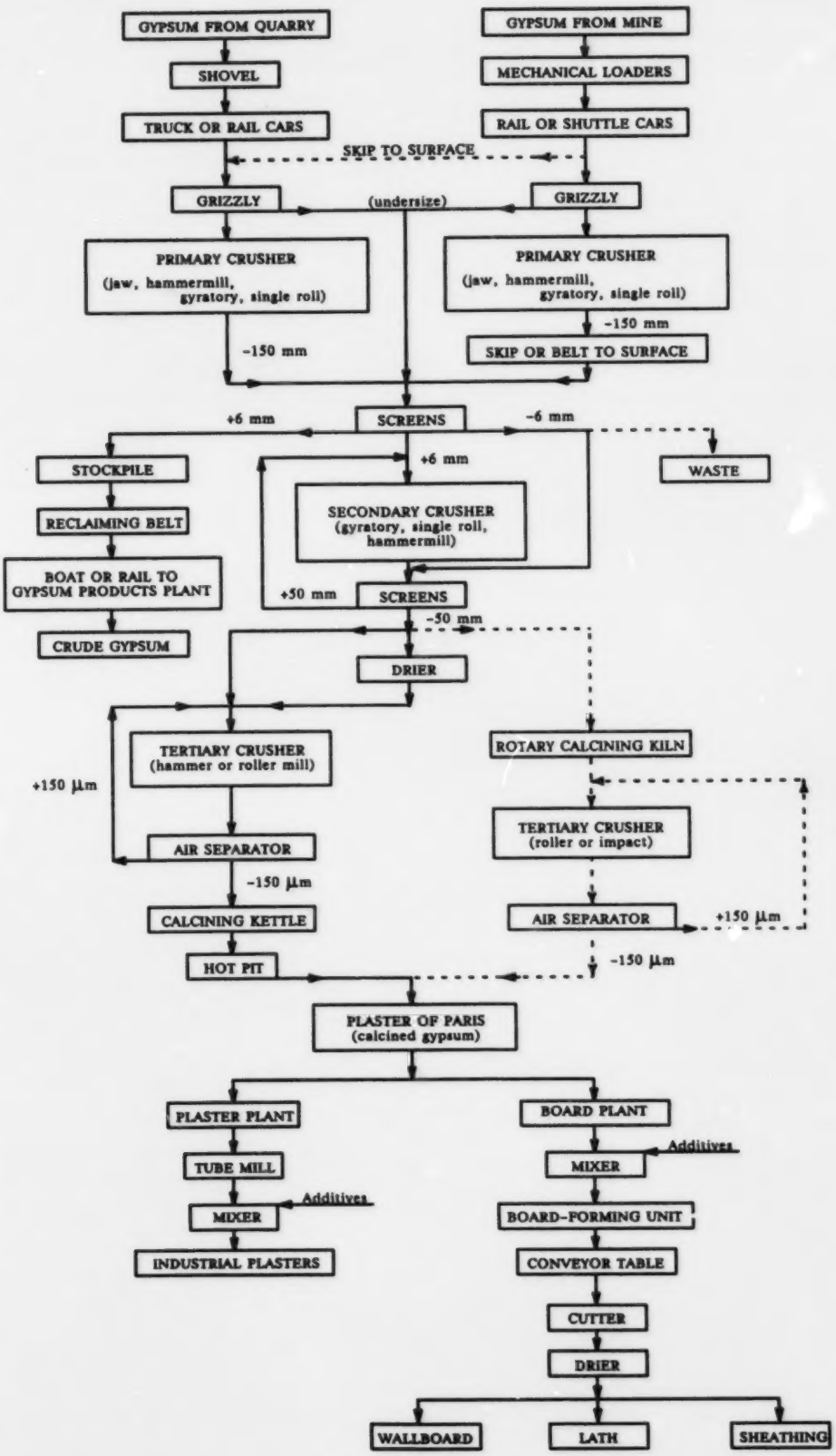


Fig. 1 – Typical flowsheet for gypsum: quarry or mine to finished products

Fig. 2 – Gypsum mines (quarries) and wallboard plants in Canada

Table 1. Canadian Gypsum Mining and Gypsum Products Manufacturing Operations for 1988

Company	Location	Operation
Newfoundland		
1. Domtar Inc.	Flat Bay	Open-pit mining – reopened in May 1988
2. Atlantic Gypsum Ltd.	Corner Brook	Wallboard manufacture
Nova Scotia		
3. Georgia-Pacific Corporation	River Denys, Sugar Camp	Open-pit mining of gypsum
4. Little Narrows Gypsum Co. Ltd.	Little Narrows	Open-pit mining of gypsum and anhydrite
5. Domtar Inc.	McKay Settlement	Open-pit mining of gypsum by contract
	Windsor	Plaster and "Gypcrete" manufacture
6. Fundy Gypsum Co. Ltd.	Wentworth and Miller Creek	Open-pit mining of gypsum and anhydrite
7. National Gypsum (Canada) Ltd.	Milford	Open-pit mining of gypsum
New Brunswick		
8. Canada Cement Lafarge Ltd.	Havelock	Open-pit mining of gypsum for cement manufacture
Quebec		
9. CGC Inc.	Montreal	Wallboard manufacture
	St-Jerome	Wallboard manufacture
10. Domtar Inc.	Montreal	Wallboard plant now used only as distribution terminal
11. Westroc Industries Limited	Ste. Catherine d'Alexandrie	Wallboard manufacture
Ontario		
12. CGC Inc.	Hagersville	Underground mining and wallboard manufacture
13. Domtar Inc.	Caledonia	Underground mining and wallboard manufacture
14. Westroc Industries Ltd.	Drumbo	Underground mining
	Clarkson	Wallboard manufacture
Manitoba		
15. Domtar Inc.	Gypsumville	Open-pit mining
	Winnipeg	Wallboard manufacture
16. Westroc Industries Ltd.	Amaranth	Open-pit mining
	Winnipeg	Wallboard manufacture
Saskatchewan		
17. Domtar Inc.	Saskatoon	Closed wallboard manufacturing plant in November, 1988
Alberta		
18. Domtar Inc.	Calgary	Wallboard and "Gypcrete" manufacture
19. Westroc Industries Ltd.	Calgary	Wallboard manufacture
British Columbia		
20. Domtar Inc.	Canal Flats	Open-pit mining
	Vancouver	Gypsum products manufacture
21. Westroc Industries Ltd.	Vancouver[1]	Gypsum products manufacture
	Windermere	Open-pit mining
	Vancouver[2]	Gypsum products manufacture

[1] Genstar plant in Vancouver acquired by Westroc Industries Limited in June 1985.
[2] Westroc Industries Limited Vancouver plant closed in June 1985.

more in length and may contain 6, 8, 10 or more decks of roller conveyors extending throughout its length. The boards are dried by hot air from an oil- or gas-fired furnace or by electric heaters. The temperature at the intake end is between 150 and 175°C and, at the discharge end, about 100°C. About 45 min are required for each board to travel through the drier. The ends of the boards are ground as they leave the drier and the boards packaged and transferred to a central warehouse.

The flowsheet, Figure 1 (5), traces the steps followed in mining and processing gypsum. The operations outlined are typical of most Canadian plants, although there may be slight variations within individual plants.

Current Developments

Gypsum mine and plant locations are noted on the map in Figure 2 and listed by producing companies, in Table 1 (8). The bulk of the gypsum quarried in Newfoundland and Nova Scotia is exported to gypsum product and cement plants in the United States and Quebec. There is only one wallboard plant in Newfoundland, at Corner Brook, and one small plaster plant in Nova Scotia, at Windsor. There are two Portland cement plants, one at Corner Brook, Newfoundland, the other at Brookfield, Nova Scotia. Production of gypsum in New Brunswick is intermittent, gypsum being produced at Havelock as required for use in Portland cement manufacture at a nearby plant.

There are three wallboard manufacturing plants in the Montreal area. All obtain their requirements of gypsum from Newfoundland and Nova Scotia as do five cement plants in southeastern Quebec. Gypsum is mined from underground deposits at three locations in southern Ontario, at Caledonia, Hagersville and Drumbo. Gypsum from the first two mines is used on-site for the production of wallboard. Gypsum from the Drumbo mine is used for wallboard manufacture at a Mississauga plant. Gypsum from these mines is also used in Portland cement manufacture at seven plants in southern Ontario.

In Manitoba, gypsum from quarries at Amaranth is used in the manufacture of gypsum wallboard at two plants in Winnipeg, and in two Portland cement plants, one at Winnipeg, the other at Fort Whyte. There is no production of gypsum in either Saskatchewan or Alberta; two wallboard plants in Calgary obtain gypsum from quarries in southeastern British Columbia, at Windermere and Canal Flats. The gypsum requirements of cement plants at Exshaw and Edmonton, Alberta, are also supplied by these same two quarries. Gypsum is quarried intermittently at Falkland, east of Kamloops, for use in Portland cement manufacture at Kamloops. There are two operating gypsum product plants in Vancouver and one cement plant. Gypsum for these facilities normally is obtained from mines on San Marcos Island, Mexico.

Two recent developments are of interest. A $65 million fibre-gypsum board plant is under construction at Point Tupper in Cape Breton, Nova Scotia, by Louisiana-Pacific Corporation of Portland, Oregon. This plant will use calcined gypsum, recycled paper and imported expanded perlite to produce a light-weight construction board for cladding interior walls of buildings. The bulk of the

finished product will be exported to markets in eastern United States. In New Brunswick, a new gypsum wallboard plant is planned for construction at McAdam, 65 km southwest of Fredericton. The plant is scheduled for completion in mid 1990 and will export the bulk of its production to markets in the United States.

The Canada–Manitoba Mineral Development Agreement recently sponsored a literature survey of energy conservation in gypsum wallboard manufacture through reduction of the water demand of calcined gypsum (10).

Production and Trade

The earliest recorded production of gypsum in Canada was 61,500 t in 1874. Apart from minor recessions during the depression and war years, production has steadily increased to an all-time record high of 9 Mt in 1987. Gypsum today is mined in six provinces – Newfoundland, Nova Scotia, New Brunswick, Ontario, Manitoba and British Columbia. Nova Scotia is by far the leading producer, annually accounting for 70% of the total Canadian production. Over 90% of the output of Nova Scotia's crude gypsum is exported, chiefly to the United States, but also to Quebec for use in gypsum products and Portland cement manufacture. Ontario, the next largest producer, annually accounts for 16% of the total production. Gypsum is used within the province for gypsum products and cement manufacture.

Imports of crude gypsum amounted to 218,000 t in 1987, over 50% of the total originating from Mexico to supply gypsum–product plants in the Vancouver area. Spain accounted for 38%, and the United States 7% of the remainder. Exports of manufactured products, largely to the United States, were valued at $158 million. Imports of manufactured products, mostly from the United States, were valued at only $22 million in 1987.

Production and trade statistics for gypsum and gypsum products for 1987 and 1988 are summarized in Table 2.

CHEMICAL GYPSUM

Chemical or synthetic gypsums, of interest as potential source material for gypsum products manufacture and for products or processes using gypsum, include phosphogypsum, fluorogypsum and sulphogypsum. Phosphogypsum is a waste by-product from phosphoric acid manufacture; fluorogypsum, a waste by-product from hydrofluoric acid manufacture; and sulphogypsum, a waste by-product from sulphate titanium dioxide operations and flue-gas desulphurizing systems at coal-burning power plants.

Table 2 – Gypsum production and trade for 1987 and 1988

	1987		1988	
	(t)	($000)	(t)	($000)
Production (shipments)				
Crude gypsum				
Nova Scotia	6 274 142	53 479	7 245 182	66 776
Ontario	1 468 215	16 547	1 452 739	15 716
Manitoba	379 759	6 060	419 356	4 936
British Columbia	535 659	5 529	x	x
Newfoundland	x	5 338	x	x
New Brunswick	x	32	x	x
Total[1]	9 093 926	86 985	9 511 581	92 544
Imports				
Crude gypsum				
Mexico	118 460	3 676	92 810	3 041
Spain	83 327	735	115 058	1 030
United States	15 675	404	66 753	1 626
Other countries	161	3	295	8
Total	217 623	4 818	274 917	5 707
Plaster of Paris and wall plaster				
United States	25 795	5 170	n.a.	854
Other countries	102	30	n.a.	433
Total	25 897	5 200	n.a.	1 287
Gypsum, lath, wallboard and basic products[2]				
United States	6 452 926	11 609	18 044 555	19 748
Other countries	74 475	112	47 022	94
Total	6 527 401	11 721	18 091 577	19 844
Total imports gypsum and gypsum products	n.a.	21 739	n.a.	27 549
Exports				
Crude gypsum				
United States	5 704 670	49 620	5 615 039	51 917
Other countries	189	84	36 247	659
Total	5 704 859	49 704	5 651 286	52 576
Gypsum lath, wallboard and basic products[2]				
United States	72 542 905	108 669	n.a.	85 215
Other countries	73 807	161	n.a.	684
Total	72 616 712	108 830	n.a.	85 899
Total exports of gypsum and gypsum products	n.a.	158 534	n.a.	138 475

Sources: Energy, Mines and Resources Canada; Statistics Canada

[1]Totals do no include gypsum produced or shipped for use by Canadian Portland cement producers.

[2]Square metres

x Confidential; n.a. Not available

Phosphogypsum

Phosphogypsum, a by-product of the phosphate fertilizer industry, is formed by the reaction of sulphuric acid on ground phosphate rock. The reaction may be represented as follows:

$$3Ca_3(PO_4)_2.CaF_2 + 10H_2SO_4 + 2H_2O \rightarrow 6H_3PO_4 + 2HF + 10CaSO_4.2H_2O$$

The gypsum formed during this reaction is separated from the phosphoric acid by filters, slurried with water and pumped to waste disposal areas. The material is finely divided, acidic and, on a dry basis, usually contains more than 90% gypsum. Common impurities include unreacted or partially reacted phosphate rock, organic material, calcium fluoride and quartz sand. The gypsum crystals may be acicular to tabular depending on the source phosphate rock and its treatment during the acid manufacturing process. Most of the phosphate rock now used in Canada is uncalcined pebble from sedimentary deposits in the United States, principally in Florida, Montana and Idaho. Phosphate rock is also obtained from Togo, Morocco and Senegal.

By-product gypsum from phosphate fertilizer facilities has been produced and stockpiled at a number of locations in Canada. These include Valleyfield and Beloeil, Quebec; Courtright, Hamilton and Port Maitland, Ontario; Medicine Hat, Calgary, Redwater and Fort Saskatchewan, Alberta; and Kimberley, British Columbia. Estimated accumulated tonnages at these locations vary between 1.5 and 10.0 Mt. Phosphogypsum produced at Belledune, New Brunswick, until recently was discarded into Chaleur Bay, and at Trail, British Columbia, into the Columbia River. At present phosphogypsum is produced at only four locations: Belledune, New Brunswick; Redwater and Fort Saskatchewan, Alberta; and Trail, British Columbia.

Research into the technical feasibility of utilizing phosphogypsum in gypsum products manufacture was initiated by CANMET in the mid-60's and a number of papers and reports (34-36) of this work were published (see also Appendix). Two conferences on phosphogypsum sponsored by the Florida Institute of Phosphate Research, Bartow, were held in Florida; the first in 1980 (37) and the second in 1988 (38). The conferences included presentations on the use and potential use of phosphogypsum in many applications. These included gypsum products (wallboard, blocks and bricks), in road construction, as a soil conditioning agent and/or source of supplemental calcium and sulphur, and for the recovery of sulphur, sulphuric acid, and by-product cement.

Technically phosphogypsum can be utilized for gypsum products manufacture. However, it is unlikely to be used in Canada because of the degree of processing required and, more importantly, because of the presence of small quantities of radium which could represent a potential radiological hazard. The radium content of Canadian phosphogypsums varies from 25 to 50 pCi/g. Until an economic process is developed to substantially reduce the level of radium, Canadian phosphogypsums will continue to be discharged and stored as unusable waste products.

Fluorogypsum

Fluorogypsum or, more correctly, fluoroanhydrite is the term commonly applied to the waste calcium sulphate produced during hydrofluoric acid manufacture. The reaction of sulphuric acid with finely ground fluorite is represented as follows:

$$CaF_2 + H_2SO_4 \rightarrow CaSO_4 + 2HF$$

The gaseous hydrofluoric acid is drawn off and condensed, and the calcium sulphate (fluoroanhydrite) is slurried with water and piped to waste disposal ponds. The finely divided fluoroanhydrite contains sulphuric and hydrofluoric acids, which are normally neutralized with lime or limestone prior to disposal. The fluoroanhydrite is gradually transformed into fluorogypsum, the hydrous form of calcium sulphate, by the action of water in the waste pond. The finely divided fluorogypsum consolidates into a hard, rock-like mass in the waste dump. Fluorogypsum is produced at several locations in Canada including Arvida and Valleyfield, Quebec, and Amherstburg, Ontario.

Interest has been expressed in the possibility of utilizing fluorogypsum as a set-control agent in Portland cement and as a raw material for gypsum products manufacture. Some research on its use in Portland cement has been reported (39-42). A study carried out in 1982 by Allied Chemical Canada Ltd., under contract to CANMET, showed that fluorogypsum from Allied's hydrofluoric acid facility at Amherstburg, Ontario, performed quite satisfactorily as a replacement for natural gypsum or anhydrite in Portland cement manufacture (42).

CANMET completed a preliminary study of the use of fluorogypsum in gypsum products manufacture in 1978 (74). On the basis of this preliminary research of various samples, it would appear that fluorogypsum has potential as raw material for gypsum products manufacture. Further research at a pilot-plant level was recommended to determine more precisely the nature of fluorogypsum, and to study more fully its behaviour on calcining and its use in gypsum products manufacture.

Sulphogypsum

Sulphogypsum is a term used to designate waste calcium sulphate produced by the lime or limestone neutralization of sulphuric acid effluents, and in some flue-gas desulphurization systems.

Hansen *et al.* (43), in a paper presented at the 1983 flue-gas desulphurization symposium (44), group flue-gas treatment technologies into four general classifications:

- wet slurry scrubbing;
- wet liquid scrubbing;
- spray drying; and
- dry absorption.

The production of by-product sulphogypsum is primarily a feature of the wet slurry scrubbing process. This process uses limestone, lime or alkaline fly ash to absorb SO_2. The resulting calcium sulphite is

then oxidized to the sulphate (gypsum). The authors noted that by-product enhancement to produce commercially saleable gypsum is in place in the United States, Japan and Germany. There is, however, no recorded production or utilization of sulphogypsum in Canada.

The recovery of sulphur from by-product gypsum for the production of sulphuric acid by the cement-sulphuric acid process is another well documented use for sulphogypsum (45).

Preliminary CANMET studies of sulphogypsum produced experimentally at titanium dioxide operations in Quebec showed this material to be of high purity and satisfactory for use in gypsum products manufacture (75,76).

Outlook

Although there is a continued high level of interest and demonstrated technical feasibility in the possibility of utilizing several synthetic gypsums for the manufacture of gypsum products and Portland cement, it is unlikely that phosphogypsum, in particular, will find wide acceptance for such purposes in Canada. Impurities in phosphogypsum would necessitate careful monitoring and process control at all stages, both during the manufacture of phosphoric acid and in the subsequent processing of the by-product phosphogypsum into gypsum products. The contained radium would further discourage use of phosphogypsum in gypsum products and possibly in Portland cement production because of the potential radiological hazard. In Europe and Japan, however, phosphogypsum is used in the manufacture of gypsum products, in cement manufacturing plants, and also for soil stabilization. Recent experiments in France have produced paper with a 20% phosphogypsum content as filler.

Fluorogypsum is perhaps a more attractive material for use in gypsum products and Portland cement, but careful controlled processing would be required to ensure complete neutralization and conversion of the fluoroanhydrite to fluorogypsum.

Sulphogypsum, if and when produced in Canada, probably would be suitable for use in gypsum products and Portland cement. Use of these last two types of gypsum for such purposes would of course be dependent upon there being an adequate source of supply of quality material at prices competitive with natural gypsum.

In the United States, Georgia-Pacific Corporation announced its intention to build a gypsum wallboard plant using synthetic gypsum provided by a Tennessee Valley Authority power plant. This particular project represents a new and unique technology, and will be the company's eleventh wallboard plant in the United States. In 1987, a wallboard plant in east Texas became the first in North America to use synthetic gypsum to manufacture wallboard.

Production of flue gas desulphurization gypsum is expected to dramatically increase as the result of strong pressure to reduce sulphur dioxide emission from power plants and smelters.

ANHYDRITE

Anhydrite deposits of Canada have been described in detail by Cole and Rogers (46). Large gypsum-associated deposits occur in Newfoundland, Nova Scotia, New Brunswick, Manitoba, Alberta and British Columbia.

Mineralogy

Anhydrite, anhydrous calcium sulphate, crystallizes in the orthorhombic system. The crystal forms are prismatic or tabular; also commonly fibrous, lamellar, granular and compact. The cleavage is perfect parallel to three pinacoids which results in rectangular fragments. The colour is white, often with a grey, blue or red tint. The lustre on cleavage planes is pearly, and on the basal plane is vitreous, transparent to subtranslucent. The fracture is uneven and splintery in lamellar and fibrous varieties. The hardness is 3.0 to 3.5 on the Mohs scale, and the specific gravity 2.7 to 3.0. Anhydrite can usually be distinguished from gypsum in the field by its blue-grey colour and hardness; gypsum can usually be scratched with a finger nail whereas anhydrite, being harder, cannot be scratched.

Technology

The manufacture of commercial plaster from anhydrite was pioneered by Victor Lefebvre in England in 1924 (46). Samples of Canadian anhydrite were evaluated and performed satisfactorily as plaster. Professor A.E. Flynn of Nova Scotia Technical College, Halifax, also studied anhydrite plasters in Canada (47). Cole and Rogers (46) undertook a detailed study of a number of Canadian anhydrites for their plaster-forming and paper-filling characteristics. Although anhydrite can be used for plaster manufacture, the ready availability of gypsum tends to discourage such use.

Production and Uses

Production of anhydrite in Canada is limited to two quarries in Nova Scotia, at Wentworth and Little Narrows. Production is estimated at 125,000 t which is mostly shipped to the United States for use as a set-control agent in Portland cement manufacture and as a fertilizer for peanut crops. Minor tonnages are also shipped to cement plants in Ontario and Quebec for use in Portland cement manufacture. Anhydrite is used as a soil additive to improve the permeability of clayey soils and to add calcium and sulphur nutrients. Anhydrite reportedly is used in Europe, especially in England and Germany, in the manufacture of ammonium sulphate, sulphuric acid and co-product cement. It may be used as a diluent for insecticides and fungicides, as a filler for paper and cotton, as a metallurgical flux, and as a road-bed material, especially in gypsum and anhydrite quarry operations.

Current Developments

Several organizations have expressed interest in the possibility of recovering sulphur and co-product calcium carbonate from Cape Breton anhydrite. Brador Minerals Inc. is currently studying the feasibility of utilizing anhydrite and coal to produce elemental sulphur and precipitated calcium carbonate in the Little Narrows area. Preliminary studies have demonstrated technical feasibility.

As part of the Canada/Nova Scotia Mineral Development Agreement, a study was carried out by the Technical University of Nova Scotia (TUNS), Halifax, on the use of anhydrite in cementitious products, particularly for backfill packing material in coal mines (48). The process incorporates fine grinding followed by wetting with an accelerator/water solution (8 to 10% by weight) containing 1 to 2% of a mixture of ferrous sulphate heptahydrate ($Fe_2SO_4.7H_2O$) and potassium sulphate (K_2SO_4). This technology has been used in German coal mines for a number of years. Testwork carried out by TUNS with anhydrite, and anhydrite/fly ash mixtures (90 to 80/10 to 20), demonstrated the technical feasibility of this technology. Reactions taking place include hydration and conversion to gypsum, setting and hardening. About 25% of the anhydrite ($CaSO_4$) was converted to gypsum ($CaSO_4.2H_2O$) in these tests and, of the four anhydrite samples tested, three performed satisfactorily. Larger scale evaluation in operating coal mines is planned.

CANMET STUDIES

Gypsum

Background

Eighteen CANMET/Mines Branch studies relating to various aspects of gypsum beneficiation were reviewed (51-68). A summary of each is presented in Appendix A. The title, report number, authors' names, and a summary of testwork and results are included.

The summary of each study includes the original sample weight, head analysis, mineralogy, beneficiation methods, beneficiation product sizes, concentrate grades and recoveries, and remarks or observations of particular interest. The original sample weight is indicative of the scale of investigation, whether bench, laboratory, semi-pilot plant or pilot plant. The head analyses provide data concerning the mineral content and whether the sample originated from a high or low-grade deposit. Mineralogical information not only identifies major and minor minerals but also provides data regarding association between minerals and host rocks. In many cases, the liberation size is either not known or not stated; however, the beneficiation product size is quoted since, by inference, product size under optimum test conditions usually equates to liberation size. Beneficiation methods

are important as a guide for future studies of deposits with similar mineral assemblages, and concentrate grade and recovery figures provide an indication of how efficient the beneficiation methods were in achieving a specification product.

Where possible, all studies common to a particular deposit are grouped together for continuity and convenience of reference. The noted gypsum studies were conducted between 1915 and 1985. Most studies were on samples from Nova Scotia, Quebec and Ontario.

Scale

Generally most studies were conducted on feed material weighing less than 60 kg; three studies (61,63,66) were made on samples weighing in excess of 200 kg.

Head analyses

The gypsum content varied from 20% gypsum for ore from Spatsum, British Columbia (67) to greater than 99% gypsum for ore from the Magdalen Islands, Quebec (59). The majority of ores were greater than 90% gypsum, and lower grade ores were characterized by the presence of dolomite.

Mineralogy

The mineralogy of the various gypsum samples was basically similar. The high-grade deposits, containing greater than 90% gypsum, were associated with minor amounts of anhydrite, calcite, dolomite, quartz and clay.

Intermediate-grade deposits, containing 65 to 90% gypsum, were usually associated with dolomite as the major mineral impurity. In one study of gypsum from Gypsumville, Manitoba (65), anhydrite was the major impurity; a gypsum sample from Caledonia, Ontario (63) was associated with limestone as the major mineral impurity.

The low-grade samples from Spatsum, British Columbia (67), were associated with quartz, calcite, dolomite, mica and pyrite.

Beneficiation

CANMET has undertaken numerous studies of Canadian gypsum samples from various locations for their possible development. Cole, in a 1930 report (4), provides details of tests on sixty-five samples of gypsum: thirty-six in Nova Scotia, thirteen in New Brunswick, three in Quebec, five in Ontario, two in Manitoba and six in British Columbia.

High-grade deposits

Gypsum beneficiation for high-grade deposits was basically straightforward involving crushing, if the sample was in lump form, and grinding to 150 μm in a buhr mill. Following size reduction, each

sample was calcined at a temperature between 80 and 225°C to produce the hemihydrate. The calcined product was finally evaluated for plaster forming ability by ASTM or CSA test procedures. The formed plaster was evaluated for colour, consistency, set time, tensile and compressive strengths. Typical values for samples which were suitable for gypsum plaster are reported in Table 3.

Table 3 – Typical gypsum and anhydrite plaster-forming results

Sample locations	Colour	Consistency mL/100 g	Set time min	Tensile strength KPa	Compressive strength KPa
Gypsum					
Ottawa Brook, N.S.	white	63	11	2227	14652
Cape Breton, N.S.	white	69[1]	11[1]	2413[1]	–
Boulardarie, N.S.	white	69	18	2310	11866
Little Narrows, N.S.	–	70	26	2138	13301[2]
		–	–		14735[3]
Newport, N.S.	–	–	–	2758	18258
Petitcodiac, N.B.	white	<---------- good strength[4] ---------->			
Magdalen Islds., Que.	sl. pink	69	13	2365	11356
Magdalen Islds., Que.	sl. pink	70	17	2641	10777
Magdalen Islds., Que.	white	74	14	1744	7922
Moose River, Ont.	white	66	22	2462	13707
Moose River, Ont.	white	68	28	2324	13425
Gypsumville, Man.	white	45	rapid	876[5]	–
Anhydrite					
Baddeck, N.S.	–	26[1]	73[1]	2103[1]	–
Baddeck, N.S.	white	–	63[1]	2690[1]	–

1 Average values
2 Cubes
3 Cylinders
4 Not enough sample for detailed evaluation
5 Low values due to the presence of anhydrite

Intermediate-grade deposits

The presence of dolomite, limestone, or anhydrite in quantities up to 20% are detrimental to the plaster forming ability of gypsum. Extensive beneficiation using a variety of wet and dry techniques was therefore employed to produce higher grade gypsum concentrates.

A comprehensive study by MacPherson (49) discusses the various merits of wet and dry beneficiation methods for producing high-grade gypsum products from relatively low-grade feed material. The techniques investigated included wet tabling, Aerofall milling with air classification, hammer mill reduction with screening, flotation, pebble mill regrinding, Aerofall mill regrinding, Raymond

pulverizer regrinding, electrostatic separation, calcination with regrinding, washing and screening, and heavy media separation.

The results of these various combinations of techniques are summarized in Table 4, and most indicate successful beneficiation to high-grade gypsum. Wet tabling and flotation are not considered economic since drying is required after processing. Autogenous milling is considered to be better than hammer milling since autogenous milling is generally cleaner, producing less dust, and gypsum is reduced to a fine product in a single pass. Regrinding of the Aerofall mill oversize in the Aerofall mill, however, was not as efficient as pebble mill or Raymond pulverizer regrinding.

Table 4 – Summary of gypsum beneficiation test results (49)

Test No.	Method of processing	Head % gypsum	Product % gypsum	Wt. %	Recy. %
1.	Wet tabling	60.0	76.0	67.8	83.4
2.	Aerofall mill and air sepn. at 75 µm	74.0	85.0	52.3	60.0
	150 µm	–	82.1	62.5	69.4
3.	Hammer mill and air sepn. at 150 µm	73.0	83.7	53.8	61.7
4.	Test 2 plus flotation[1]	74.0	83.3	80.0	90.0
5.	Test 2 plus wet tabling[1]	74.0	84.1	76.0	86.4
6.	Test 2 plus pebble mill regrind[1]	74.0	82.5	84.1	92.0
7.	Test 2 plus Aerofall regrind[1]	75.0	81.8	78.6	86.9
8.	Test 2 plus Raymond pulverizer[1]	74.0	81.0	84.0	92.0
			79.7	87.5	94.2
9.	Test 2 plus electrostatic sepn.[1]	74.0	84.2	86.1	98.0
10.	Rotary calciner plus regrind	74.0	80.0[2]	85.7	94.1
11.	Washing and screening	77.5	83.1	89.4	95.8
12.	Sink and float	77.5	79.9	89.1	91.3

[1] Minus 75 µm Aerofall mill product included in grade and recovery computations
[2] Hemihydrate

Electrostatic separation was successful but the chief disadvantage to its use on a commercial scale is the cost of heating and cooling, the methods necessary to obtain separation. Wet screening is preferred to dry screening because clay can only be removed completely by wet screening.

Miscellaneous techniques

Wet jigging and tabling of a sample of gypsum from Amaranth, Manitoba (64), successfully separated gypsum from dolomite. The minus 10 mm plus 5 mm fraction was concentrated from 75% to 96.7% gypsum by jigging; tabling of the minus 1 mm fraction produced 90.9% gypsum.

Colour sorting is also reported to successfully concentrate gypsum (50).

Malhotra (51) developed and tested a unique ring-tensile strength test method for evaluating gypsum plasters.

Chemical Gypsum

Background

Collings *et al.* conducted eight studies on the beneficiation of by-product chemical gypsum for possible use as gypsum plaster. Five studies were concerned with phosphogypsum (69–73), one with fluorogypsum (74), and two with sulphogypsum (75,76).

A summary of each study is presented in Appendix B. The title, report number, author's names and a summary of testwork and results are included.

Scale

The phosphogypsum samples weighed between 40 and 150 kg, although several samples from Fort Saskatchewan, Alberta, weighed only 10 kg (73). The sulphogypsum samples were larger, weighing between 330 and 650 kg. The weight of the fluorogypsum sample was not recorded.

Head analyses

The phosphogypsum and sulphogypsum samples were all high grade, analyzing greater than 90% gypsum. The fluorogypsum sample was lower grade, analyzing about 70% gypsum (74).

Mineralogy

The mineralogy of each variety of chemical gypsum was dependent on the original minerals from which the by-product gypsum was obtained. Phosphogypsum samples contained minor apatite, quartz and carbon; one sample also contained tourmaline (70). Sulphogypsum samples contained minor amounts of hemihydrate and quartz, while fluorogypsum samples contained minor amounts of fluorite, quartz and anhydrite.

Beneficiation

The impurities in most phosphogypsum samples occurred in the plus 150 μm to plus 300 μm fractions, so that wet screening removed a considerable portion of the impurities. Following wet screening, samples were thoroughly washed to reduce acidity and neutralized with basic hydroxides. Each sample was then calcined and tested for gypsum plaster characteristics by standard methods. Pre- and post-calcination grinding increased the Blaine surface area, but grinding before calcination reduced the plaster strength characteristics of one sample (69).

Sulphogypsum did not require wet screening to remove impurities; the only pre-calcination beneficiation being grinding to 150 μm to increase the Blaine surface area. Each sample was calcined and tested for gypsum plaster characteristics by standard methods.

Fluorogypsum samples were processed by grinding to 150 μm before calcination. Calcined products were evaluated using standard test procedures.

Phosphogypsum, sulphogypsum and fluorogypsum products from each of the studies were considered suitable for the manufacture of gypsum plaster.

Anhydrite

Background

Three CANMET studies of anhydrite were conducted by Rogers (77–79). One study provided details of tests on thirteen samples of anhydrite: eight from Nova Scotia, three from New Brunswick, and one each from Manitoba and British Columbia (77).

A summary of each study is presented in Appendix C. The title, report number, author's names and a summary of testwork and results are included.

Scale

The samples from four provinces (77) represented a combined weight of 1300 kg which indicated extensive pilot–scale testwork.

Head analyses

The analyses of samples in each of the studies were all greater than 90% $CaSO_4$ indicating high–grade anhydrite.

Mineralogy

The associated minerals were generally minor amounts of gypsum, dolomite and calcite.

Beneficiation

The beneficiation of anhydrite is basically similar to that of gypsum except that anhydrite is ground with catalytic agents, zinc sulphate and potassium sulphate, before calcining. The purpose of these agents is to reduce shrinkage and efflorescence in the plaster products. All three studies determined that the anhydrite samples were suitable for plaster manufacture. Typical results for two studies are reported in Table 3.

CONCLUDING COMMENTS

This report is the seventh in the Summary Report series on industrial minerals. It is hoped that the information presented in these and subsequent reports will be useful to all who have interest in industrial minerals in Canada.

A wide distribution of the Summary Report series is planned as a means of encouraging interest in the further development of industrial minerals for use in many diverse applications, e.g., fillers for everyday products such as paint and rubber, and in the high-technology sector for products such as high-performance plastics, silicon chips and fibre-optic filaments.

The authors encourage feedback from reports in this series. Comments and suggestions for further R&D will be invaluable to CANMET and associated government and industry groups in planning and conducting research on industrial minerals.

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APPENDIX A

SUMMARIES OF CANMET GYPSUM STUDIES

CANADA

Identification	:	**Can. – 1 (Ref. No. 51)***
Report – Title	:	STRENGTH TESTS ON GYPSUM PLASTER
– Author	:	V.M. Malhotra
– No. and Date	:	*Division Report 68–3 IR*, 1968
Sample Description	:	Commercial plaster of Paris.
Objective	:	To compare standard ASTM** or CSA*** methods for testing the tensile strengths of gypsum plaster with a CANMET ring–tensile strength method.
Processing	:	The tensile and compressive strengths of gypsum plaster were evaluated as follows: tension tests on rings and briquettes, and compression tests on cubes, all being cast for identical mixes and cured under standard conditions for seven days. A total of 425 test specimens were evaluated.
Results	:	The tension tests on rings appears to be a satisfactory means of determining the tensile strength of gypsum plaster. The tensile strength of plaster as determined by the ring–tension method is higher than that obtained by the ASTM tension test on briquettes. Results are more consistent, however, than those obtained with the compression tests on cubes and the tension tests on briquettes.
Potential Use	:	The ring–tension test method is a viable alternative to standard CSA or ASTM methods for determining the strength of gypsum plaster.

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*CANMET Identification with Reference No. in brackets

**American Society for Testing Materials

***Canadian Standards Association

These organizations are referred to in this report by their abbreviations.

NOVA SCOTIA

Identification	:	N.S. - 1 (Ref. No. 52)
Report - Title	:	TESTING OF GYPSUM FROM OTTAWA BROOK
- Author	:	R.A. Rogers
- No. and Date	:	*Ore Dressing Investigation Report 736*, 1932
Sample Description	:	10 kg of white gypsum with narrow dark bands of impurity analyzing 91.65% $CaSO_4.2H_2O$, 4.11% $CaSO_4$, and associated with minor calcium and magnesium carbonates.
Objective	:	Evaluation as a source of gypsum for gypsum plaster manufacture.
Processing	:	Samples were crushed by jaw crusher and rolls, and ground to 150 μm in a buhr mill. The ground product was then calcined in a small electric kettle to a maximum temperature of 157°C; product was tested using standard procedures.
Results	:	Plaster evaluation Colour - white Consistency - 63 mL water/100 g of plaster Time-of-set - 11 min Tensile strength - 2,227 KPa Compressive strength - 14,652 KPa
Potential Use	:	Suitable for manufacture of gypsum plaster and gypsum plaster products.

Identification	:	N.S. - 2 (Ref. No. 53)
Report - Title	:	GYPSUM SAMPLES FROM CAPE BRETON
- Author	:	R.A. Rogers
- No. and Date	:	*Ore Dressing Investigation Report 776*, 1936
Sample Description	:	Six 1 kg samples of compact, white to grey-white gypsum from various locations in Victoria county, containing from 91.3% to 98.0% $CaSO_4.2H_2O$ with minor anhydrite, calcium and magnesium carbonates.
Objective	:	Evaluation as a source of gypsum for gypsum plaster manufacture.
Processing	:	Samples were crushed by jaw crusher and ground in a pebble mill for 4 h; ground samples were then calcined in a small electric kettle. The calcining temperature was difficult to maintain because of the small sample weights, thus the final temperature varied between 163°C and 223°C; products were tested using standard procedures.
Results	:	Plaster evaluation Colour - white Consistency - 66 to 70 mL water/100 g of plaster Time-of-set - 8 to 14 min Tensile strength - 2,069 to 2,758 KPa
Potential Use	:	Suitable for manufacture of gypsum plaster and gypsum plaster products.

Identification	:	**N.S. – 3 (Ref. No. 54)**
Report – Title	:	GYPSUM FROM BOULARDARIE ISLAND, CAPE BRETON
– Author	:	R.A. Rogers
– No. and Date	:	*Ore Dressing Investigation Report* (not numbered), 1936
Sample Description	:	Two samples, No. 1 – 15 kg, No. 2 – 40 kg, each in lump form and white to light brown in colour, analyzing 98 and 97% $CaSO_4.2H_2O$ and associated with minor anhydrite, calcium and magnesium carbonates.
Objective	:	Evaluation as a source of gypsum for gypsum products manufacture.
Processing	:	Samples were reduced by jaw and roll crusher to 800 µm and portions of each combined. The resulting sample was ground to 150 µm in a buhr mill and calcined at 138°C in a 25 kg laboratory kettle; product was tested as per standard procedures.
Results	:	Plaster evaluation Colour – white Consistency – 69 mL water/100 g of plaster Time-of-set – 18 min Tensile strength – 2,310 KPa Compressive strength – 11,866 KPa
Potential Use	:	Suitable for manufacture of gypsum plaster and gypsum plaster products.

Identification	:	**N.S. – 4 (Ref. No. 55)**
Report – Title	:	GYPSUM FROM LITTLE NARROWS
– Author	:	R.A. Rogers
– No. and Date	:	*Ore Dressing Investigation Report* (not numbered), 1937
Sample Description	:	60 kg of weathered gypsum, white to light-brown in colour and analyzing 94% gypsum, 3.5% anhydrite, 2% calcium carbonate with minor magnesium carbonate.
Objective	:	Evaluation as a source of gypsum for gypsum plaster manufacture.
Processing	:	Sample was reduced to 150 µm by stage crushing using jaw and roll crushers and buhr mill. A 25 kg sample was calcined in a small laboratory kettle at 132°C. Plaster cubes, briquettes and cylinders were cast with the calcined product for tensile strength determinations; products were tested using standard procedures.
Results	:	Plaster evaluation Consistency – 70 mL water/100 g of plaster Time-of-set – 26 min Tensile strength – 2,138 KPa Compressive strength – 13,301 KPa (cubes) – 14,735 KPa (cylinders)
Potential Use	:	Suitable for manufacture of gypsum plaster and gypsum plaster products.

Identification	:	N.S. - 5 (Ref. No. 56)
Report - Title	:	TESTING OF GYPSUM FROM FOX QUARRY, NEWPORT
- Author	:	C.H. Freeman
- No. and Date	:	*Ore Dressing Investigation Report* (not numbered), 1938
Sample Description	:	60 kg of compact, white to light-brown gypsum analyzing 92% gypsum, 4% anhydrite and 3% calcite.
Objective	:	Evaluation as a potential source of commercial gypsum.
Processing	:	Reduction to 75 μm by jaw crusher and Munson buhr mill followed by calcining at a maximum temperature of 171°C in a 22 kg laboratory kettle. Calcined products were tested for strength using standard test procedures.
Results	:	Plaster evaluation Tensile strength - 2,758 KPa Compressive strength - 18,258 KPa
Potential Use	:	Suitable for manufacture of gypsum plaster and gypsum plaster products.

Identification	:	N.S. – 6 (Ref. No. 57)
Report – Title	:	COLOUR IMPROVEMENT OF PLASTER OF PARIS FROM WINDSOR
– Author	:	R.K. Collings
– No. and Date	:	*Industrial Minerals Report 288*, 1954
Sample Description	:	A number of small samples of commercial plaster of Paris and a colour comparison standard sample.
Objective	:	To improve the colour of the supplied commercial plaster of Paris sample using additives.
Processing	:	The colour or "whiteness" of the commercial plasters were compared to the standard sample using a Densichron optical density meter. A blue dye, Monastral Fast Blue G, was then added to make the plaster "appear" whiter and the colour again checked.
Results	:	The standard plaster sample was "white" in colour, whereas the supplied commercial samples were slightly pink. The addition of a small amount (0.0005%) of blue dye improved the colour slightly, however, further additions caused the plaster to take on a distinct blue tinge. The reflectivity of the treated samples were 91.3, 89.2 and 80.5%; the samples contained 0.0005%, 0.005%, 0.05%, respectively, of the blue dye.
Potential Use	:	Not determined.

NEW BRUNSWICK

Identification	:	**N.B. – 1** (Ref. No. 58)
Report – Title	:	INVESTIGATION OF GYPSUM FROM PETITCODIAC
– Author	:	R.K. Collings
– No. and Date	:	*Industrial Minerals Report 384*, 1956
Sample Description	:	2.5 kg of clay-coated, lump gypsum analyzing 99% $CaSO_4.2H_2O$ with minor anhydrite and quartz.
Objective	:	Evaluation as a potential source of gypsum for gypsum plaster and gypsum plaster products manufacture.
Processing	:	The sample was crushed by jaw crusher, ground to 150 μm, and calcined at an average temperature of 118°C in a small electric calciner. The calcined product was then mixed with water to form plaster.
Results	:	The small size of sample did not permit detailed evaluation. The set plaster, however, was white in colour and showed good strength.
Potential Use	:	Results indicated that this gypsum has potential as source material for gypsum plaster manufacture.

QUEBEC

Identification : Que. - 1 (Ref. No. 59)

Report - Title : TESTING OF GYPSUM FROM MAGDALEN ISLANDS
- Author : R.A. Rogers
- No. and Date: *Ore Dressing Investigation Report 720*, 1929

Sample Description : Lump samples of gypsum from three islands; Amherst, Grindstone and Alright. The Amherst Island sample was faintly pink and had a fibrous banded texture. The Grindstone Island sample was also pink and fibrous, but with thin lenses of red clay. The Alright Island sample was mottled grey-white and more massive in texture. Chemical analyses indicated that all three samples were >99% $CaSO_4.2H_2O$.

Objective : Evaluation as potential sources of gypsum for gypsum plaster and plaster products manufacture.

Processing : Samples were washed to remove adhering clay, crushed in a hammer mill, and ground in a buhr mill to 150 µm. Twenty-five kg lots of each sample were then calcined in an electrical gypsum kettle at 143°C to 154°C.

The calcined products were tested and evaluated using standard test procedures.

Results : Plaster test data:

	Amherst	Grindstone	Alright
Colour	faintly pink	faintly pink	white
Consistency (mL of water/g of plaster)	69	70	74
Time-of-set (min)	13	17	14
Tensile strength (KPa)	2365	2641	1744
Compressive strength (KPa)	11356	10777	7922

Potential Use : Suitable as source material for gypsum plaster and gypsum plaster products manufacture.

ONTARIO

Identification : **Ont. - 1 (Ref. No. 60)**

Report - Title : GYPSUM FROM MOOSE RIVER
- Author : R.A. Rogers
- No. and Date: *Ore Dressing Investigation Report 763*, 1935

Sample Description : Two 40 kg samples; each white with brown spots and analyzing 94% $CaSO_4.2H_2O$ with minor anhydrite, calcium and magnesium carbonates.

Objective : Evaluation as a potential source of gypsum for gypsum plaster and plaster products manufacture.

Processing : Samples were crushed by jaw crusher and ground to 150 µm in a buhr mill. Twenty-five kg of each sample were then calcined in an electrical kettle to a maximum temperature of 154°C (sample 1) and 175°C (sample 2). The calcined products were tested and evaluated using standard test procedures.

Results : Plaster test data:

	Sample 1	Sample 2
Colour	white	white
Consistency (mL water/100 g plaster)	68	68
Time-of-set (min)	22	28
Tensile strength (KPa)	2,462	2,324
Compressive strength (KPa)	13,707	13,425

Potential Use : Results indicate that these gypsum samples have good potential as source material for gypsum plaster and plaster products manufacture.

Identification : **Ont. - 2** (Ref. No. 61)

Report - Title : BENEFICIATION OF GYPSUM FROM CALEDONIA
- Author : R.K. Collings
- No. and Date : *Industrial Minerals Report 479*, 1957

Sample Description : 900 kg of ground gypsum analyzing about 72% $CaSO_4.2H_2O$ and associated with dolomite which tended to concentrate in the coarser, plus 150 µm size fraction.

Objective : To investigate air separation as a method for reducing the dolomite impurity.

Processing : Three separators were evaluated; Raymond lab separator, Hardinge gyrotor air classifier, and the Gayco air separator.

Results : Results indicated that the gypsum content could be improved marginally through separation of the coarse, plus 150 µm, high-dolomite fractions. Final results are summarized as follows:

Separator	Weight % minus 150 µm	Grade % gypsum	Recovery %
Raymond	74.6	76.7	83.6
Hardinge	75.7	77.8	86.2
Gayco	65.5	75.5	72.7

Remarks : Too low grade; further beneficiation to remove the dolomite is necessary.

Potential Use : Not determined.

Identification	:	**Ont. - 3 (Ref. No. 62)**
Report - Title	:	COLOUR SORTING OF GYPSUM FROM DRUMBO
- Author	:	F.H. Hartman
- No. and Date	:	*Division Report 62-53 (IR)*, 1962
Sample Description	:	50 kg of unprocessed gypsum.
Objective	:	Beneficiation of gypsum by colour sorting.
Processing	:	Crushing and screening into four sizes; minus 15 mm plus 10 mm, minus 10 mm plus 5 mm, minus 5 mm plus 2.5 mm and minus 2.5 mm. Processing of the three coarsest sizes was conducted with a Sortex colour sorting machine to produce white, grey and dark fractions.
Results	:	White fractions varied from 91.2 (finest) to 97.6% gypsum (coarsest); grey fractions from 90.1 to 88.7% gypsum; dark fractions from 73.3 to 76.1% gypsum; minus 2.5 mm fraction analyzed 90.6% gypsum. Recovery of white, grey, and minus 2.5 mm fractions was 82%.
Potential Use	:	Suitable for gypsum products manufacture.

Identification	:	**Ont. - 4 (Ref. No. 63)**
Report - Title	:	**BENEFICIATION OF LIMESTONE-ASSOCIATED GYPSUM FROM CALEDONIA**
- Authors	:	**J.M. Lamothe and S.S.B. Wang**
- No. and Date	:	***Division Report 85-18 (IR)*, 1985**
Sample Description	:	500 kg of gypsum up to 150 mm in size analyzing 70% $CaSO_4.2H_2O$; principal impurity was limestone.
Objective	:	To upgrade the sample to 80% $CaSO_4.2H_2O$ by selective removal of the limestone impurity.
Processing	:	Crushing followed by differential grinding and sizing using impact and attritor mills; sizing followed by air tabling; milling followed by sizing and air tabling.
Results	:	Gypsum content of the crushed and sized fractions of the head sample varied from 66% for the minus 20 mm plus 5 mm, to 86% for the minus 150 μm fraction. The unsized sample was upgraded to 76 to 77% $CaSO_4.2H_2O$ with good recovery; however, attempts to improve grade to 80% resulted in sharply reduced recoveries.
Potential Use	:	Not determined.

MANITOBA

Identification	:	**Man. - 1** (Ref. No. 64)
Report - Title	:	SEPARATION OF GYPSUM AND DOLOMITE FROM AMARANTH
- Author	:	R.K. Carnochan
- No. and Date	:	*Ore Dressing Investigation Report 736*, 1932
Sample Description	:	90 kg of white gypsum containing buff-coloured dolomite in sizes ranging from 5 mm through to 75 mm and analyzing 75% gypsum and 20% dolomite.
Objective	:	Production of high-grade gypsum.
Processing	:	A number of processes were studied including jigging, wet tabling, flotation, calcining followed by screening, and calcining followed by grinding and air separation.
Results	:	Jigging produced a concentrate analyzing 96.7% gypsum using sizes between minus 10 mm plus 5 mm, and tabling produced a concentrate analyzing 90.9% gypsum using minus 1 mm sizes; recoveries by each method were only fair. Flotation gave poor results, but fair grades were obtained by calcining followed by screening and regrinding in a Raymond pulverizer fitted with a "throw-out" attachment for discarding dolomite. However, none of the methods produced a clean separation of dolomite from gypsum.
Potential Use	:	Not determined.

Identification	:	**Man. - 2** (Ref. No. 65)
Report - Title	:	GYPSUM FROM GYPSUMVILLE
- Author	:	R.A. Rogers
- No. and Date	:	*Ore Dressing Investigation Report 776*, 1936
Sample Description	:	8 kg of gypsum from the White Elephant quarry analyzing 66% gypsum and 32% anhydrite with minor calcium and magnesium carbonates.
Objective	:	Evaluation as a potential source of gypsum for plaster and plaster products manufacture.
Processing	:	The sample was reduced to about 1 mm and calcined in an electric oven at a temperature of 82°C to 160°C. The calcined product was ground in a pebble mill, screened at 150 µm, and the minus 150 µm fraction tested and evaluated using standard CSA test procedures.
Results	:	Plaster test data: Colour - white Consistency - 45 mL water/100 g plaster Time-of-set - rapid set Tensile strength - 876 KPa Low consistency and rapid set were due to anhydrite in the sample.
Potential Use	:	Possibly suitable for gypsum products manufacture with further beneficiation to remove anhydrite.

BRITISH COLUMBIA

Identification	:	**B.C. - 1** (Ref. No. 66)
Report - Title	:	TESTING OF GYPSUM FROM BULL RIVER
- Authors	:	L.H. Cole and C.H. Freeman
- No. and Date	:	*Ore Dressing Investigation Report* (not numbered), 1939
Sample Description	:	200 kg of grey dolomitic gypsum analyzing 73.25% gypsum, 0.87% anhydrite and 17.0% dolomite.
Objective	:	Removal of dolomite and evaluation as a potential source of gypsum for plaster manufacture.
Processing	:	The sample was crushed to 5 mm by jaw crusher and to 2 mm by roll crusher. A sample of the 2 mm product was calcined in an electric kettle to a maximum temperature of 154°C. One portion of the calcined product was ground in a Raymond pulverizer and air classified into three sized fractions; the plaster-forming characteristics were determined for the fines, coarse and clean-up. A second portion of the 2 mm product was calcined at 149°C, and the product screened at 300 μm; the plus 300 μm fraction was separated by air tabling.
Results	:	Results for both series of tests showed some improvement in product quality but the presence of dolomite resulted in only fair results.
Potential Use	:	Too low grade for gypsum products applications.

Identification	:	**B.C. - 2** (Ref. No. 67)
Report - Title	:	BENEFICIATION OF GYPSUM FROM SPATSUM AND SKOOKUMCHUCK
- Author	:	R.K. Collings
- No. and Date	:	*Mineral Processing Test Report 60-128*, 1960
Sample Description	:	Lot 1: Two small samples from Spatsum, one finely divided, the other in lump form analyzing about 20% gypsum. The principal impurities were quartz, carbonates, mica and pyrite. Lot 2: A sample from Skookumchuck analyzing 95% gypsum in alternate layers or bands of white and grey. The principal impurities were dolomite and clay.
Objective	:	Evaluation as source of commercial gypsum.
Processing	:	Selective crushing and sizing to determine whether impurities were concentrated in either the coarse or fine sizes.
Results	:	One of the Spatsum samples was upgraded from 18 to 40% gypsum with a recovery of 23% by selective crushing and removal of the plus 150 μm fraction. The Skookumchuck sample was upgraded from 95 to 97% gypsum with a recovery of 44% as minus 150 μm.
Potential Use	:	The Skookumchuck gypsum would be satisfactory for use in gypsum products manufacture.

YUKON

Identification	:	**Yuk. - 1 (Ref. No. 68)**
Report - Title	:	INVESTIGATION OF GYPSUM FROM YUKON TERRITORY
- Author	:	R.K. Collings
- No. and Date	:	*Mineral Processing Test Report 61-48*, 1961
Sample Description	:	A 35 kg sample of white gypsum, 100-150 mm in size, analyzing 90% gypsum, 6% calcite, 4% anhydrite. The sample location was near the Haines-Yukon highway, 100 km north of Haines.
Objective	:	Evaluation as a source of commercial gypsum.
Processing	:	Sample was reduced to 100 µm by hammer and buhr mills and calcined at an average temperature of 125°C in a 25 kg kettle. Consistency, time-of-set and strength determinations were made on the calcined product using standard CSA methods.
Results	:	Strength tests equalled or exceeded CSA standards. The purity, superior white colour, plaster forming and high strength characteristics of the calcined product makes this gypsum an ideal material for use by the gypsum products industry.
Potential Use	:	Suitable for gypsum products manufacture.

APPENDIX B

SUMMARIES OF CANMET CHEMICAL GYPSUM STUDIES

ONTARIO

Identification	:	**Ont. – 6** (Ref. No. 69)
Report – Title	:	INVESTIGATION OF PHOSPHOGYPSUM FROM PORT MAITLAND
– Author	:	R.K. Collings
– No. and Date	:	*Investigation Report 62-67*, 1962
Sample Description	:	Three samples, each minus 150 μm in size and weighing 45 kg, and identified as lagoon, filter and filter cake; lagoon sample was white, the filter and filter cake samples were grey. Impurities included unreacted phosphate rock, quartz, and carbon which concentrated in the coarse, plus 300 μm fractions.
Objective	:	Evaluation as a source of gypsum for gypsum products manufacture.
Processing	:	Test calcination of a small fraction of each sample showed discolouration of product due to carbon, particularly in the filter and filter cake samples. Subsequent testwork incorporated thorough washing to remove carbon, removal of plus 300 μm impure fraction, drying, calcining and product evaluation using the ASTM standard test procedure.
Results	:	Beneficiation improved the strength characteristics. Grinding, especially before calcining, appeared to have a detrimental effect on the strength characteristics.
Potential Use	:	Suitable for gypsum plaster and plaster products manufacture.

Identification	:	**Ont. - 7 (Ref. No. 70)**
Report - Title	:	AUTOCLAVE CALCINATION OF PHOSPHOGYPSUM SAMPLES
- Authors	:	R.K. Collings and D. Karpoff
- No. and Date	:	*Investigation Report 67-89*, 1967
Sample Description	:	Samples A and B from a fertilizer complex at Port Maitland; A - 50 kg, analyzing 94.2% gypsum, B - 150 kg, analyzing 95.9% gypsum, light grey colour, largely minus 150 μm in size. The chief impurities, quartz and apatite, with minor tourmaline and carbonate, were concentrated in the plus 150 μm sizes.
Objective	:	Evaluation as a source of gypsum for gypsum products manufacture.
Processing	:	Fifty-eight calcining tests were conducted in a small laboratory autoclave for 1 to 2.5 h, at 110°C to 160°C and 207 to 586 KPa. Removal of the plus 150 μm fraction prior to calcining, sulphuric acid treatment during calcination and/or following calcination, and the removal of excess liquor effectively nullified the retarding effect of phosphate. The products were evaluated for time-of-set and bond to gypsum wallboard paper.
Results	:	Initial tests using untreated gypsum resulted in wet plaster (stucco) that thickened slowly and required several days to harden (set) and develop strength. Further study and investigation indicated that unreacted phosphate, which in addition to being concentrated in the plus 150 μm fractions, was also believed to be chemically combined with the gypsum, probably was chiefly responsible for the delayed set. Close set control was achieved, in particular, by the addition of controlled quantities of sulphuric acid to the dewatered autoclave stucco. The product set and hardened quickly to form a strong plaster which bonded well with gypsumboard paper and, although acidic, did not appear to exhibit any marked detrimental effects.
Potential Use	:	Suitable for gypsum plaster and plaster products manufacture.

Identification	:	**Ont. – 8 (Ref. No. 71)**
Report – Title	:	EVALUATION OF PHOSPHOGYPSUM FROM PORT MAITLAND FOR GYPSUM PRODUCTS MANUFACTURE
– Authors	:	R.K. Collings and G.A. Brown
– No. and Date	:	*Investigation Report 71–10*, 1971
Sample Description	:	85 kg sample of a composite of filter cake samples. The sample was grey, composed of finely divided crystal agglomerates, and analyzed 94% gypsum. Impurities, mostly unreacted phosphate and quartz, were concentrated in the plus 200 μm sizes, pH was 3.5.
Objective	:	Evaluation as a source of gypsum for gypsum products manufacture.
Processing	:	Wet screening to remove the plus 200 μm fraction and to reduce residual acid, followed by calcining in a laboratory calciner at 150°C over a 1.5 h period. Pre– and post–calcination grinding produced a 3000 to 6000 cm^2/g (Blaine) surface area; final neutralization was accomplished with various bases (calcium and sodium hydroxides). Wallboard formation trials were conducted using standard CSA procedures.
Results	:	The results of this study indicated that phosphogypsum from Port Maitland has potential as a substitute for gypsum in gypsum products manufacture. Fabricated products compared favourably with those made with natural gypsum, specifically with regard to setting characteristics, strength and bond of the plaster core to gypsum wallboard paper.
Potential Use	:	Suitable for gypsum products manufacture.

QUEBEC

Identification	:	**Que. - 2** (Ref. No. 72)
Report - Title	:	EVALUATION OF PHOSPHOGYPSUM RESIDUE FROM VALLEYFIELD FOR GYPSUM PRODUCTS MANUFACTURE
- Authors	:	R.K. Collings, D. Karpoff and G.A. Brown
- No. and Date	:	*Division Report 71-9 (IR)*, 1971
Sample Description	:	Two filter cake samples, No. 1 - 40 kg and No. 2 - 80 kg; samples were grey and finely divided with carbon, unreacted phosphate and quartz impurities in the plus 200 μm sizes. Each sample was acidic at pH 3.0 to 3.5.
Objective	:	Evaluation as a source of gypsum for gypsum products manufacture.
Processing	:	Wet screening to remove the plus 200 μm fraction and reduce acidity with final neutralization using various basic hydroxides. Calcining of samples was conducted over a 1 to 1.5 h period in a gypsum kettle. Pre- and post-calcination grinding produced a surface area of 3000 to 6000 cm^2/g (Blaine); wallboard-forming trials were conducted.
Results	:	The results of this study indicated that phosphogypsum from Valleyfield has potential as a substitute for natural gypsum in gypsum products manufacture. Fabricated products, evaluated by CSA standards testing, generally compared favourably with those made with natural gypsum, specifically with regard to setting characteristics, strength and bond of the plaster core to gypsum wallboard paper.
Potential Use	:	Suitable for gypsum products manufacture.

ALBERTA

Identification	:	Alta. - 1 (Ref. No. 73)
Report - Title	:	EVALUATION OF PHOSPHOGYPSUM FOR WALLBOARD MANUFACTURE
- Authors	:	R.K. Collings and D. Karpoff
- No. and Date	:	*Investigation Report 70-45*, 1970
Sample Description	:	Eight samples from fertilizer plants at Fort Saskatchewan and Redwater, each weighing from 10 to 100 kg and analyzing 90 to 95% gypsum; mostly minus 150 μm in size. Associated impurities included unreacted or partially reacted phosphate, and quartz.
Objective	:	Evaluation as sources of gypsum for gypsum products manufacture.
Processing	:	Processing included removal of impurities by screening out the plus 150 μm fraction and calcining the minus 150 μm fraction over a 1 to 1.5 h period at a maximum temperature of 150°C to 160°C in a 4.5 kg Benco reactor and a 22 kg calcining kettle. The calcined product (stucco) was evaluated using standard testing procedures. Particle size distribution, pH and bond to gypsum wallboard paper were measured. Various alkali bases were used to neutralize the acidic stucco prior to paper-bonding tests.
Results	:	Processing of this material, although complicated by its acid nature, was relatively straightforward. A satisfactory bond to gypsum wallboard paper was obtained with a basic ground stucco (5000 cm^2/g Blaine, pH 8 to 10) containing 0.5% starch. A good bond was also obtained with a less basic, lower surface area stucco (3000 cm^2/g Blaine, pH 7 to 8) containing 1.0% starch.
Potential Use	:	Suitable for gypsum products manufacture.

QUEBEC/ONTARIO

Identification	:	**Que. – 3/Ont. –9** (Ref. No. 74)
Report – Title	:	EVALUATION OF FLUOROGYPSUM FOR GYPSUM PRODUCTS MANUFACTURE
– Authors	:	R.K. Collings and G.A. Brown
– No. and Date	:	*Division Report 78–7*, 1978
Sample Description	:	Two samples, one from Valleyfield, Quebec, the other from Amherstburg, Ontario; each analyzed >70% gypsum. The Valleyfield sample weighed 25 kg and was composed of 100 mm lumps. Associated impurities were anhydrite, quartz and fluorite; pH was 5.4. The Amherstburg sample weighed 25 kg and was finely divided and moist; pH was 8.1.
Objective	:	Evaluation as a source of gypsum for gypsum products manufacture.
Processing	:	Portions of the high–grade gypsum samples from each location were crushed to about 150 mm by jaw crusher and disc pulverizer and calcined in a calcining kettle. Calcined products were evaluated using standard test procedures. Bond of the calcined products to gypsum wallboard was also checked.
Results	:	Products made with the two noted samples compared favourably with commercial plasters; compressive strengths, although slightly below that typically exhibited by commercial plasters, were well above the CSA requirement. Bond of these plasters to gypsum wallboard paper was generally satisfactory.
Potential Use	:	Suitable for gypsum products manufacture.

QUEBEC

Identification	:	Que. – 4 (Ref. No. 75)
Report – Title	:	EVALUATION OF SULPHOGYPSUM SAMPLES FROM VARENNES FOR GYPSUM PRODUCTS MANUFACTURE
– Authors	:	R.K. Collings and G.A. Brown
– No. and Date	:	*Division Report 79–3 (IR)*, 1979
Sample Description	:	330 kg of sulphogypsum, produced experimentally by limestone neutralization of spent sulphuric acid, analyzing 92% $CaSO_4.2H_2O$; white to grey-white and 90% minus 150 μm in size.
Objective	:	Evaluation as a potential source of gypsum for gypsum products manufacture.
Processing	:	Unground samples, and samples ground to 150 μm by pebble mill, were calcined in a laboratory kettle at 150°C over a 3–h period. Calcined products were evaluated using standard CSA test methods; bond of the plaster to gypsum wallboard paper was also investigated.
Results	:	A satisfactory plaster of Paris was produced with this material; however, grinding to 5000 cm^2/g Blaine prior to calcining was required to improve the performance and fluidity of the plaster. The bond to gypsum wallboard paper was improved by the addition of starch.
Potential Use	:	Suitable for gypsum products manufacture.

Identification	:	**Que. - 5 (Ref. No. 76)**
Report - Title	:	EVALUATION OF SULPHOGYPSUM SAMPLES FROM TRACY FOR GYPSUM PRODUCTS MANUFACTURE
- Authors	:	R.K. Collings and G.A. Brown
- No. and Date	:	*Division Report 79-5 (IR)*, 1979
Sample Description	:	650 kg of sulphogypsum, produced experimentally by limestone neutralization of spent sulphuric acid, analyzing 94.6% gypsum with traces of the hemi-hydrate (bassanite) and quartz. The pH was 6.5, the size minus 200 μm, and the gypsum was well crystallized.
Objective	:	Evaluation as a potential source of gypsum for gypsum products manufacture.
Processing	:	Unground samples and samples ground to 150 μm by pebble mill were calcined in a laboratory kettle to 150°C over a 3-h period. Calcined products were evaluated using standard CSA methods; bond of plaster to gypsum wallboard paper was investigated.
Results	:	The material is technically satisfactory for use in gypsum products; however, grinding prior to calcining was recommended to maximize the charge to the kettle, and to improve workability and quality of the calcined products. The bond to gypsum wallboard paper was improved by the addition of 1% starch.
Potential Use	:	Suitable for gypsum products manufacture.

APPENDIX C

SUMMARIES OF CANMET ANHYDRITE STUDIES

CANADA

Identification	:	Can. – 1 (Ref. No. 77)
Report – Title	:	THE EXAMINATION OF ANHYDRITE FROM CANADIAN DEPOSITS
– Author	:	R.A. Rogers
– No. and Date	:	*Ore Dressing Investigation Report* (unnumbered), 1932
Sample Description	:	Thirteen lump samples from various provinces including N.S., N.B., Man. and B.C., representing a combined weight of 1300 kg. Analysis based on LOI varied from 0.06 to 8.55%, the latter value indicating some conversion to gypsum.
Objective	:	To evaluate as source of gypsum plaster.
Processing	:	Samples were separately crushed by a gyratory crusher and ground in pebble mill, buhr mill or disc pulverizer to 150 μm. A 2 kg sample of each of the thirteen ground samples was further ground in a pebble mill for 4 h with 0.5 to 5.0% of various inorganic chemical salts, e.g., carbonates, chlorides and sulphates. Products were formed into plaster using distilled water and tensile strengths were determined.
Results	:	Tensile strengths were in the order of 3400 KPa. Shrinkage of briquettes used for tensile strength determination was significant and surface salt efflorescence common. Shrinkage and efflorescence could be overcome using zinc and potassium sulphates as catalyzers.
Potential Use	:	Suitable for plaster manufacture.

NOVA SCOTIA

Identification : N.S. - 7 (Ref. No. 78)

Report - Title : TESTING OF ANHYDRITE FROM BADDECK
- Author : R.A. Rogers
- No. and Date : *Ore Dressing Investigation Report* (not numbered), 1952

Sample Description : A 35 kg sample of grey anhydrite analyzing 95% anhydrite ($CaSO_4$), 0.48% gypsum, 0.10% $MgCO_3$ and 3.39% $CaCO_3$.

Objective : Evaluation of plaster-making characteristics.

Processing : The sample was crushed to minus 850 µm by jaw and rolls crusher. Four, 2 kg samples were each ground in a pebble mill with 1.5% $ZnSO_4$ and 1% K_2SO_4 for 240, 120, 60 and 12 min; products were formed into plaster and strength determined.

Results : Results indicated that a satisfactory plaster could be made from this anhydrite. The water requirement varied from 21 to 31 mL per 100 g of plaster; the time-of-set from 57 to 90 min, and tensile strength from 1931 to 2275 KPa. The set plaster showed little evidence of shrinkage and salt efflorescence. The sample that was ground for only 12 min appeared to form as good a plaster as samples ground for longer periods.

Potential Use : Suitable for plaster manufacture.

Identification	:	**N.S. - 8 (Ref. No. 79)**
Report - Title	:	TESTING OF ANHYDRITE FROM NOVA SCOTIA
- Author	:	R.A. Rogers
- No. and Date	:	*Ore Dressing Investigation Report* (not numbered), 1934
Sample Description	:	Six small samples from near Sydney, N.S. Each appeared compact and all were blue-grey in colour. Analysis indicated 90.6 to 97.0% anhydrite with minor gypsum and calcite.
Objective	:	To investigate plaster-making qualities of these anhydrite samples.
Processing	:	Samples were individually crushed to pass 840 μm. Plasters were made using "catalytic agents", 1.5% $ZnSO_4$ and 1% K_2SO_4, after pebble mill grinding to 75 μm. The products were tested for fineness, time-of-set, and tensile strength.
Results	:	The time-of-set varied from 50 to 75 min, and tensile strength from 2069 to 3310 KPa. The colour of set plaster was white, and there was little shrinkage or salts efflorescence.
Potential Use	:	Suitable for manufacture of gypsum plasters.